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A Multi-National Simulation Framework for Maritime Missile Defense

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ABSTRACT: *The Maritime Theater Missile Defense (MTMD) Forum is an eight-nation informal body formed in 1999 to create international cooperation in the area of Maritime Theater Missile Defense. Although initially set up for maritime ballistic missile defense, the Forum has evolved to consider cooperation in other mission areas, such as land attack and ship self defense. The Forum has established focused working groups to address specific technical areas (e.g., radars, BMC4I) to identify common needs, harmonize future operational requirements and nurture possible collaborative development programs. The Modelling and Simulation Working Group (MSWG) was established in 2001 when the Forum realized that modelling and simulation (M&S) would play an important role in developing, testing and evaluating the projected systems that enable sea based missile defense.*

The mission of the MSWG is to establish a multinational developed-and-managed M&S framework for Maritime Missile Defense and related mission areas. The purpose of the common M&S framework is to enable development and assessment of MTMD concepts, algorithms, and concepts-of-operations, by providing a setting for national M&S capabilities to be exercised in an international context. The framework will allow nations to analyze performance and interoperability within a coalition capability, and experiment with coalition tactics and doctrine to achieve MTMD objectives. It will support analysis from weapon system to battle force level, permitting nations to identify & analyze capability gaps and relate them to specific systems performance.

The MSWG is developing the M&S framework incrementally, following a roadmap that includes collaborative efforts with other MTMD Forum working groups. The primary mechanism for implementing development is a set of international Project Arrangements (PA). Currently, the MSWG is embarking on the implementation of its first PA, among The Netherlands, Germany, and the U.S. It establishes a three-nation HLA federation demonstrating trans-national distributed simulation of ballistic missile defense. It implements an international lower-tier MTMD simulation capability wherein ship, systems, threat, and environment simulations are interoperated using a common federation architecture (i.e., functional allocation, concept model, interface protocols, etc.).

This paper describes the multi-national framework for MTMD M&S and describes the current developments in the first Project Arrangement. The paper also describes how MSWG efforts relate to national issues, and the roadmap for nations to develop and make use of the common M&S framework.

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1. MTMD & the Role of the Modelling & Simulation

The Maritime Theater Missile Defense (MTBMD) Forum is an international body formed in 1999 for the purpose of fostering international cooperation in the area of MTMD. The Forum's objective is cooperatively develop and demonstrate international capabilities in support of the design and evaluation of components, combat, control, and management systems that comprise the family of systems that enable sea-based missile defense. The MTMD Forum currently comprises eight participating nations: Australia, Canada, Germany, Italy, Netherlands, Spain, United Kingdom, and United States. The Forum was originally established as an informal body, but has

completed negotiations to formalise a Memorandum of Understanding under which formal Project Arrangements can be executed.

MTMD Forum activities are supported by a set of topic area working groups, as shown in Figure 1 below. Among the most active working groups is the Modelling and Simulation Working Group (MSWG). The mission of the MSWG is to establish a multi-national developed-and-managed modelling and simulation (M&S) framework for maritime missile defense and related mission areas. The MSWG is developing this M&S framework via a 5-10 year incremental development process following a roadmap.

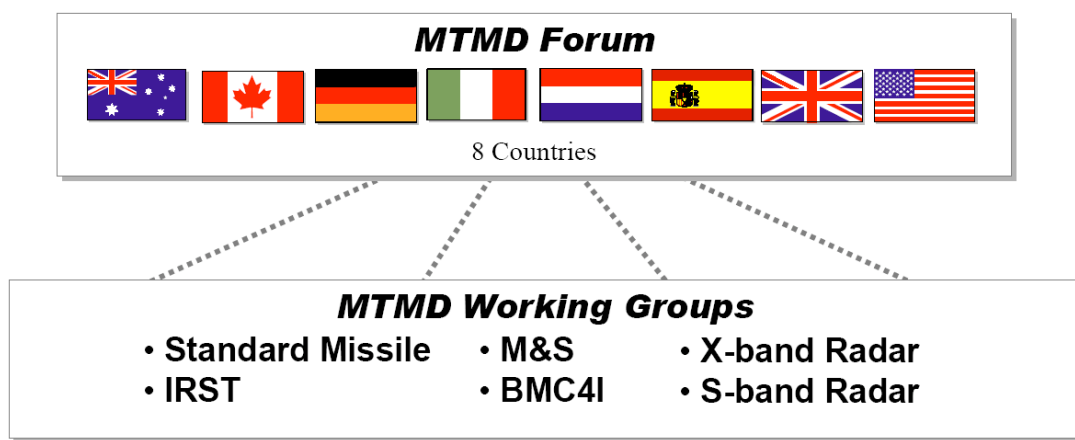


Figure 1: MTMD Forum Structure

The Forum's overarching requirements for M&S usage are several¹. M&S is expected to enable development and assessment of MMD concepts, algorithms, and CONOPs in a framework that includes international system representations. Specific analyses aided through the use of an MSWG framework include:

- C2 analyses and developments
- Sensor & weapon performance capability, including requirements definition
- Track formation & management
- Coalition tactics & doctrine development
- Softkill performance / ship signature management

The framework must support MTMD analysis at multiple levels of granularity, from weapon system to force-level. At the weapon system level, the framework must support

requirements determination for systems via interoperable engineering-level simulation. At the coalition battle force level, the framework must support interoperability analysis including flexible selection of force/systems mixes. Overall, the MSWG is expected to act as the mechanism for cohesion across working groups, where its M&S system engineering products play an important role in realising comparable results across all specialty areas.

2. Why a Common Framework? The Problem Space and National Perspectives

The general Maritime Theater Missile Defense problem space is depicted in Figure 2 below:

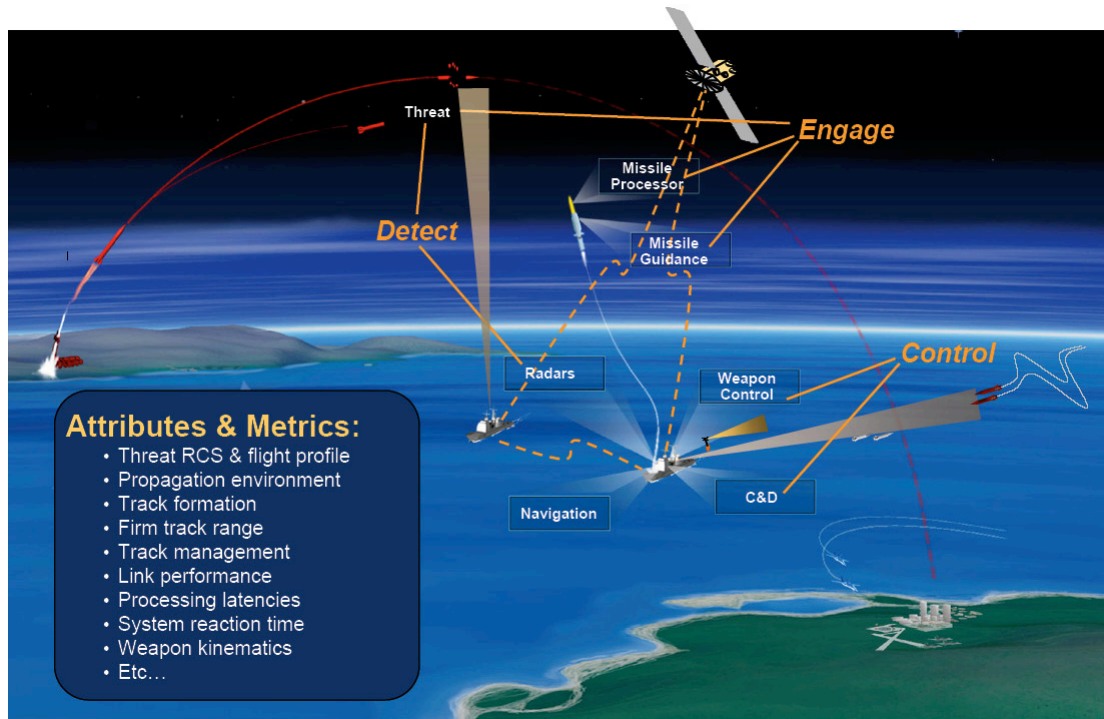


Figure 2: MTMD Problem Space

The battle space contains a number of warships and air/space assets, with each asset having either or both sensor and weapon capabilities. Launched weapons may function autonomously or semi-autonomously. The various MTMD systems may comprise various combinations of different nations' systems. These systems together must perform effective Battle Management C⁴I. Threat systems include targeting systems, launchers, and threat missiles. And, of course, all of these systems experience and interact with one another through a single, dynamic natural environment. Not surprisingly, there are a large number of attributes and metrics to be represented and managed in an M&S representation, some of which are listed in the Figure 2 above.

However, the specific questions to be asked, and therefore the specific attributes and metrics of interest will vary according to the problem space perspective. If one is interested in addressing BMC⁴I questions, then the perspective on the problem space yields Figure 3. If one is instead interested in addressing weapons engagement questions, then the perspective on the problem space shifts to Figure 4. Note that each has some unique representation issues, while some are common. Even for common aspects, however, the M&S requirements may vary, for example in the fidelity required. Specifically, a BMC⁴I problem may require threat signature information, but not to the detail required to ask radar performance questions for a weapons engagement problem. Yet, an effective M&S framework is required that can support analyses for all MTMD problem space perspectives.

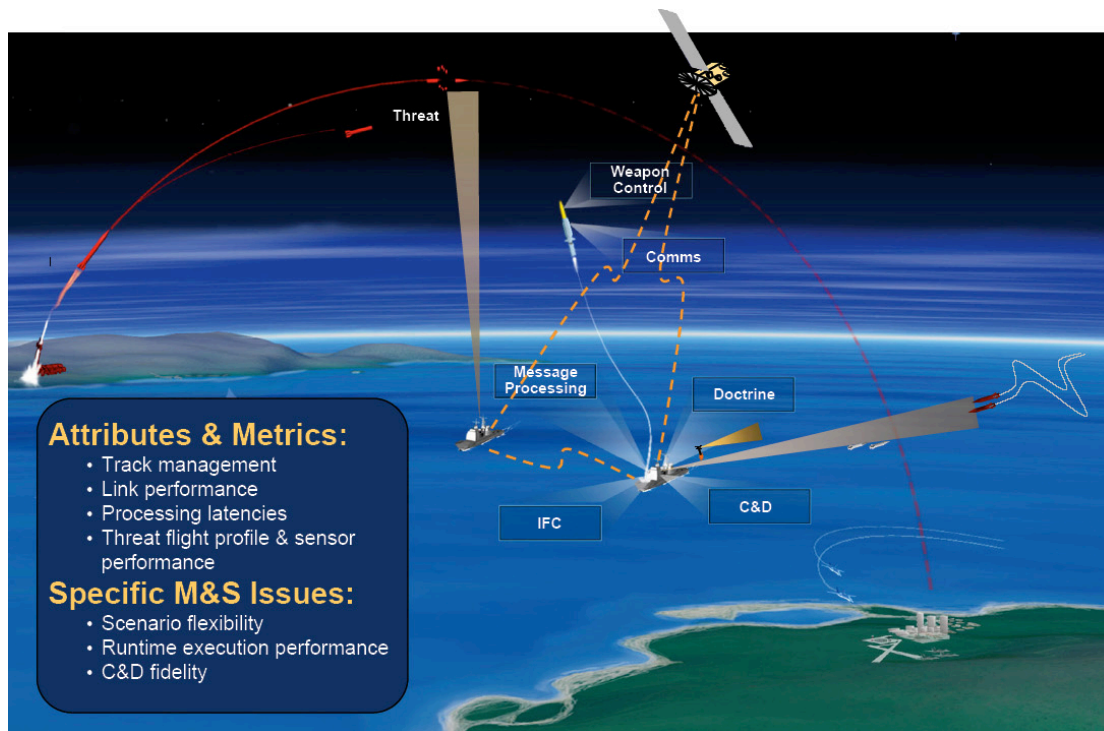


Figure 3: Problem Space Perspective – BMC⁴I

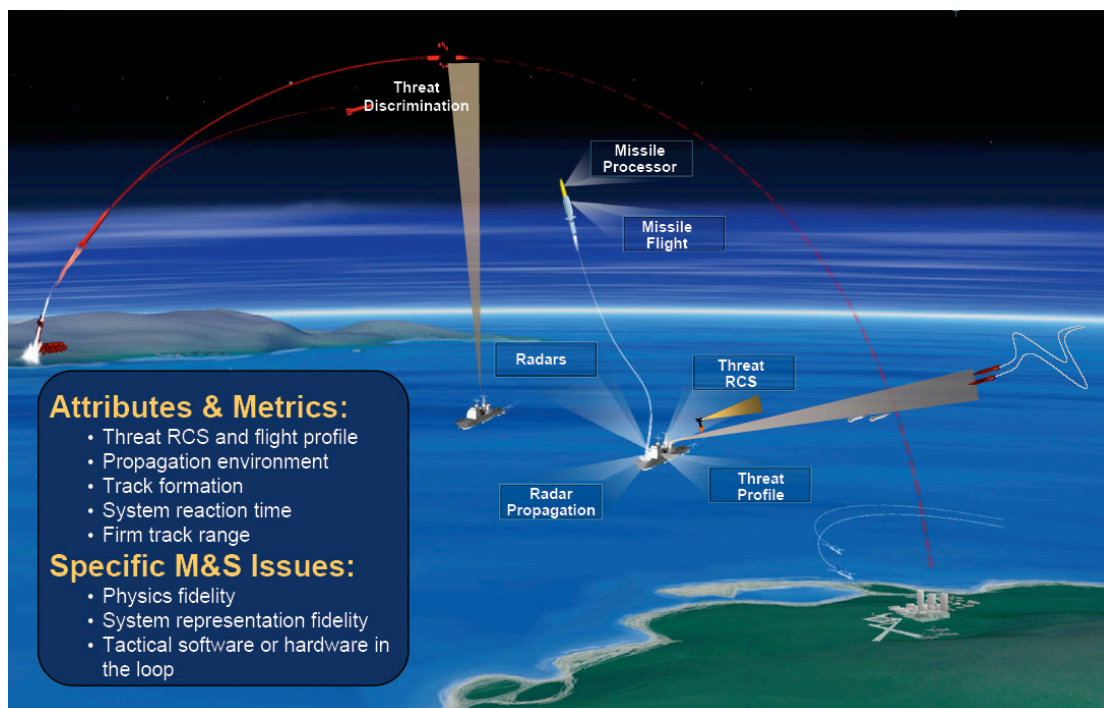


Figure 4: Problem Space Perspective – Weapons Engagement

Most importantly, the MTMD nations carry into these technical perspectives a similar national perspective. That

is the various nations are concerned with similar questions when applying M&S to MTMD problems.

In general, nations find themselves wishing to ask a (performance-related) question, but needing to represent a system/capability they don't currently own within the context of their systems. This currently leaves each nation with a set of M&S-related problems:

- can't easily or readily buy/borrow a "shrink-wrapped" representation
- don't want to have to build one
- do want to conduct the experiment, not buy an answer (do want control of the assumptions, fidelity, and focus)
- do want to cooperate with coalition members to find an international solution

Together, the set of MTMD Forum nations are asking very similar questions. Each brings national capabilities, but is asking how best to interoperate with coalition nations. The Forum nations are seeking tools to experiment with coalition tactics and doctrine to achieve MTMD objectives. Each nation wants to be able to identify & analyze capabilities & capability gaps and relate to systems performance. When a capability need is recognized, each nation wants to be able to make trades

within a broad trade space that includes international systems.

Hence, the need for a common M&S framework to enable the nations to cooperatively overcome their individual limitations and open the trade space for addressing their MTMD issues.

3. MTMD M&S Framework: the 'Virtual Range'

To meet the M&S needs of the MTMD Forum, the MSWG is developing a reference framework for interoperable M&S that is useful to all working groups and participating nations^{1,2,3}. This framework is founded on HLA-based runtime simulation, but is also founded in rigorous M&S system engineering. That is, the pre- and post-runtime components of the framework are equally important to the runtime results for success.

A top-level view of the framework is given in Figure 5 below:

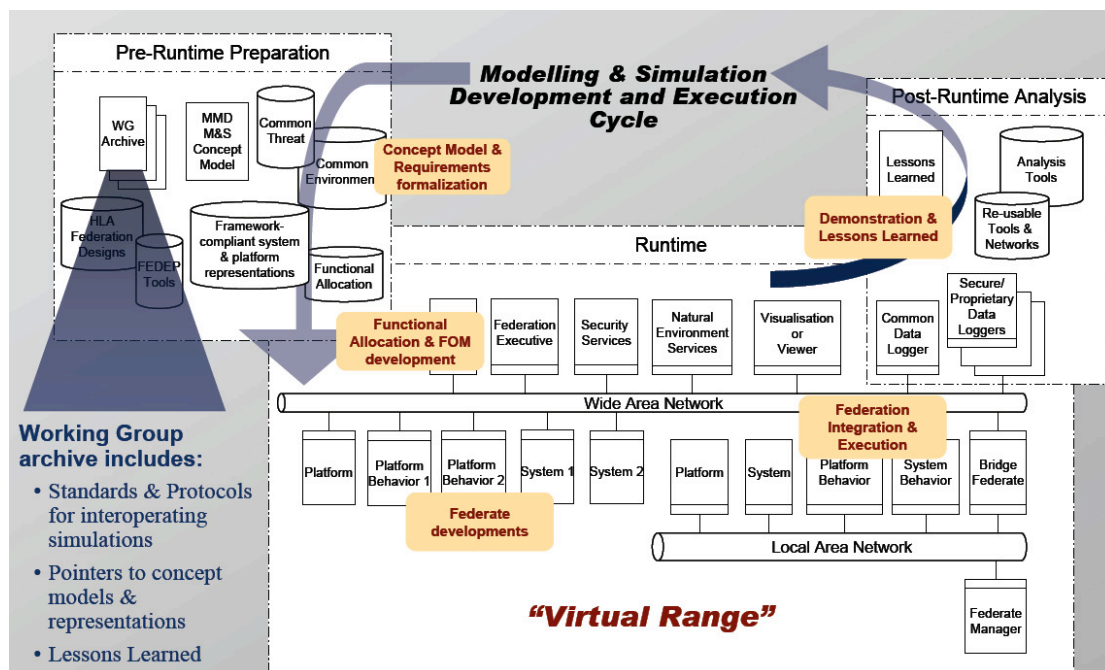


Figure 5: MTMD M&S Reference Framework

Implementation of the Framework occurs in spirals via a consistent system engineering process. Each cycle leverages consistent materials for "pre-runtime" engineering and preparation. The MSWG will have archived materials for reference, including agreed standards and protocols for interoperating simulations via

HLA. Pre-runtime framework assets include common threat and environment definitions.

An important aspect of the common MTMD corporate knowledge base is a set of concept models that can be re-used and tailored for specific federation implementations.

Starting from a common concept model foundation enables the various working groups to avoid repeating descriptions & definitions of shared problem space components, while maintaining consistency with their brethren.

Post-runtime framework tools and capabilities are be very similar, and both pre- and post-runtime activities will include libraries of lessons learned. The MSWG is also looking to make available re-useable tools for post-runtime data extraction and analysis.

The heart of the M&S framework is a common architecture for interoperating MTMD system and battle space representations, i.e., an HLA framework. The MSWG is developing a standard FOM, federation agreements, and other standards to enable networked simulations of MTMD systems to be exercised together in a “virtual range”. The basic premise is to permit nations to connect their representations to other nations via secure wide area networks, to together address their shared problem space issues. The framework’s rules and protocols encompass matters of federation management, security, fidelity, common components (e.g., natural environment), time management, and data logging & visualisation.

The framework itself will not contain stored copies of models. Rather it will provide pointers to models and simulations owned by the individual nations, along with elucidating information about specific M&S capabilities. This will allow each nation to make available M&S assets for use in the framework without losing ownership or configuration control. Thus, the M&S framework will

function as a “distributed repository” for the M&S assets of all the MTMD Forum nations.

3.1 Roadmap for M&S Framework Development

A major step towards development of the MTMD M&S common framework is execution of the first Project Arrangement under the MTMD MOU. This Project Arrangement, ‘PA1’, is a cooperative development by Germany, Netherlands, and U.S. It implements a shared simulation of international lower tier MTMD capability. The federation is being implemented across a trans-Atlantic, tri-nation secure network. It simulates extended anti-air warfare lower-tier scenarios for weapons engagements. It includes engineering simulations of the MTMD threat, interceptor, Smart L/APAR radar suite, ownship, and natural environment. It represents the first implementation of the common federation protocols, interfaces, and FOM. Development of the PA1 federation is expected to be completed in mid-2005.

In parallel, the MSWG is pursuing a roadmap of efforts to forward the common M&S framework^{4,5} (see Figure 6). These include cooperative efforts with other MTMD Forum working groups and individual nations. The intent is to maximize direct involvement in the MSWG and direct usage (therefore improvement) of the M&S framework. Some efforts will be culminated in formal Project Arrangements, while others will leverage national or informal cooperative experiments. Currently, the MSWG is specifically liaising with the BMC⁴I working group, who are themselves negotiating a PA that requires shared M&S capabilities to be successful.

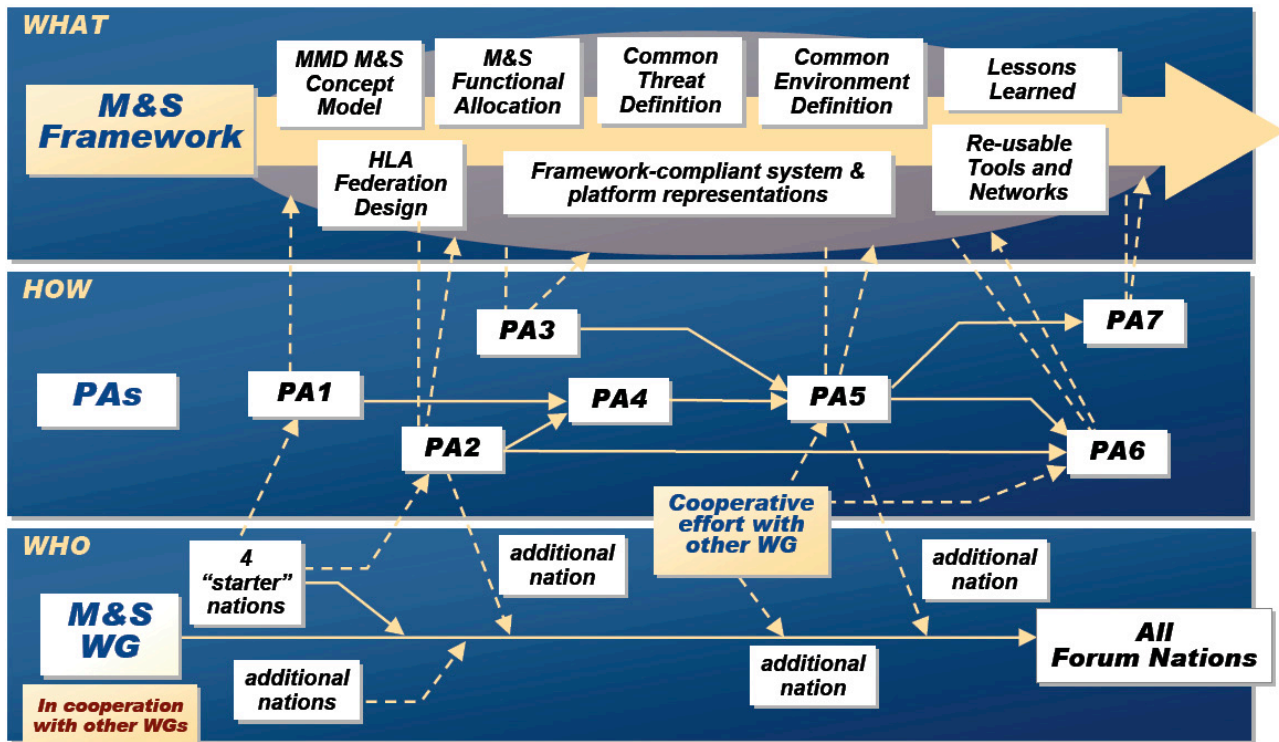


Figure 6: MTMD M&S Working Group Roadmap

4. Summary & Next Steps

The Maritime Theater Missile Defense Forum is an eight-nation body that is fostering cooperative international capabilities in support of the design and evaluation of components, combat, control, and management systems that enable sea-based missile defense. Forum nations bring some individual issues, but share a common technical perspective of the problem space. They also share a common understanding that modelling and simulation M&S will play an important role in developing, testing and evaluating the projected systems that enable sea based missile defense.

The MTMD Forum has established a Modelling and Simulation Working Group whose primary objective is development of a multinational developed-and-managed M&S framework for MTMD. The purpose of the common M&S framework is to enable development and assessment of MTMD concepts, algorithms, and concepts-of-operations, by providing a setting for national M&S capabilities to be exercised in an international context. The framework will allow nations to analyze performance and interoperability within a coalition capability, and experiment with coalition tactics and doctrine to achieve MTMD objectives.

MSWG activities and M&S framework development are following a roadmap that includes both formal Project Arrangements and informal studies. The MTMD Forum's first PA will be focused on M&S and will realize the first major framework milestone. The PA1 federation establishes a three-nation HLA federation demonstrating trans-national distributed simulation of ballistic missile defense. It implements an international lower-tier MTMD simulation capability wherein ship, systems, threat, and environment simulations are interoperated using a common federation architecture (i.e., functional allocation, concept model, interface protocols, etc.).

The next steps for the MSWG along the roadmap include direct liaison with the other Forum working groups, to determine:

- What issues are they dealing with?
- Are there opportunities for cooperative development?
- What data should be included in the international M&S Framework for Maritime Theater Missile Defense?

The next specific project will likely be cooperative work with the BMC4I working group, who bring a different problem space perspective than PA1's yet some common M&S needs.

5. References

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Author Biographies

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